

**A. FRONT COVER/TITLE PAGE**

**TITLE OF RESEARCH PROJECT:**

EFFECTS OF QUALITY COMPOSTS AND OTHER ORGANIC AMENDMENTS  
AND THEIR HUMIC AND FULVIC ACID FRACTIONS ON THE  
GERMINATION AND EARLY GROWTH OF  
SLICKSPOT PEPPERGRASS (*LEPIDIUM PAPILLIFERUM*) AND SWITCHGRASS  
IN VARIOUS EXPERIMENTAL CONDITIONS

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NAME OF CONTRACTOR: UNIVERSITA' DI BARI

CONTRACT NO: W911NF-08-1-0076-P00002 and P00003

PURCHASE REQUEST PROJECT NOR: W90C2K1251EN01

**5<sup>th</sup> and 6<sup>th</sup> INTERIM REPORT**

REPORT PERIOD: APRIL 1, 2010 - MARCH 31, 2011

**END OF FRONT COVER/TITLE PAGE**

<b>Report Documentation Page</b>			<i>Form Approved OMB No. 0704-0188</i>		
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1. REPORT DATE <b>JAN 2012</b>	2. REPORT TYPE	3. DATES COVERED <b>01-04-2010 to 31-03-2011</b>			
4. TITLE AND SUBTITLE <b>Effects of Quality Composts and Other Organic Amendments and Their Humic and Fulvic Acid fractions on the Germination of Slickspot Peppergrass (<i>Lepidium Papilliferum</i>) and Switchgrass in Various Experimental Conditions</b>		5a. CONTRACT NUMBER	5b. GRANT NUMBER		
6. AUTHOR(S) <b>Nicola Senesi</b>		5c. PROGRAM ELEMENT NUMBER	5d. PROJECT NUMBER	5e. TASK NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>University of Bari,Biology and Chemistry of Agro-Forestry and Environmental Studies ,Via G. Amendola 165/A,Bari, Italy,</b>		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>31</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## B. BODY OF THE REPORT

### (1) SCIENTIFIC WORK DONE DURING THE REPORTING PERIOD

Subject: Germination and early-growth of switchgrass (*Panicum virgatum L.*)

During the 5<sup>th</sup> and 6<sup>th</sup> semester (3<sup>rd</sup> year) of this research, a series of experiments was performed in order to evaluate the effects of three humic acids (HAs, respectively GC-HA, MC-HA and GCC-HA) isolated from the three selected composts under study, a green compost (GC), a mixed compost (MC) and green coffee compost (GCC), on the germination of two switchgrass species, Shawnee and Alamo, and the effects of substrates obtained by mixing with a peat sample (P) the three composts at three different percentages (respectively, C/P 5%, C/P 10% and C/P20%) on the early growth of these switchgrass species.

### 2. Experimental

#### *2.1. Germination*

N. 60 seeds of each switchgrass species were previously soaked in distilled water for 12 h, successively placed in three Petri dishes (20 seeds for each dish) on filter paper and added with distilled water (control) or each of three HAs at concentrations of 10, 50 and 200 mg L<sup>-1</sup>. The three HA suspensions, were prepared by dissolving the amount of each HA in few drops of KOH 0.1 M and then bringing them to the final volume with bidistilled water to reach a final pH ranging from 6.5 to 6.8.

On the basis of results obtained from the previous germination experiments of slickspot peppergrass (*Lepidium papilliferum*, see Report n. 2), an additional experiment was performed on switchgrass species in order to assess the possible beneficial or inhibitory effects of a nutrient medium on the germination process. In this experiment, n. 60 seeds of each switchgrass species were previously soaked in distilled water for 12 h, successively placed in three Petri dishes (20 seeds for each dish) on filter paper and added with the Nitsch nutrient solution diluted 1:2 with distilled water as the germination medium.

In all cases, the Petri dishes were placed in a thermostated chamber in the dark and subjected to temperature cycles of 12 h at 18 °C and 12 h at 13 °C. After 2, 5, and 8 days, the germinated seeds were counted, and after 8 days the primary root and shoot lengths were measured. All experiments were conducted in triplicate and data obtained were statistically analyzed by one-way analysis of variance (ANOVA) at 95% and 99% confidence levels. The mean values obtained for the different treatments were separated by using the least significant difference test (LSD).

## 2.2. *Early-growth*

The early-growth experiments were performed on the germinated seeds (seedlings) of each switchgrass species collected from the Petri dishes immediately after the end of the germination. N. 5 seedlings were collected from each Petri dish and transplanted into plastic pots containing different growth substrates (three pots for each treatment). The substrates used were the following: (i) only peat (P) for seedlings collected from the control; (ii) a mixture at 5% (v/v) of each compost (C) and P (C/P 5%) for seedlings collected from the treatments with the corresponding HA at concentration of 10 mg L<sup>-1</sup>; (iii) a mixture at 10% (v/v) of each C and P (C/P 10%) for seedlings collected from the treatments with the corresponding HA at concentration of 50 mg L<sup>-1</sup>; (iv) a mixture at 20% (v/v) of each C and P (C/P 20%) for seedlings collected from the treatments with the corresponding HA at concentration of 200 mg L<sup>-1</sup>. For each substrate, the electrical conductivity (EC) and pH value of its suspension in distilled water (1:15, w/v) were measured by using conventional procedures.

The pots were then placed in a thermostated chamber where seedlings were allowed to grow for a period of 25 days in the following conditions: 12-h photoperiod, temperature of 23 °C during the illumination period and 18 °C during the dark period, and constant humidity of 65%. Twice in the week, each pot was added with 5 mL of the Nitsch nutrient solution diluted 1:4 with distilled water. At the end of the experiments, the length of roots and shoots, the primary leaf, and the plant fresh weight were measured. All experiments were conducted in three replicates and data obtained were statistically analyzed by ANOVA at 95% and 99% confidence levels, and the mean values obtained for the different treatments were separated by using the least significant difference test (LSD).

### 3. Results

#### *3.1. Composts, humic acids and compost/peat mixtures*

The main physical and chemical properties of the three composts and the three isolated HA fractions are summarized in Table 1. These properties were comparatively presented and discussed in detail in the first report of this Project.

The EC and pH values of the suspensions in distilled water of the growth substrates used (1:15, w/v) are shown in Table 2. Peat (P) showed a much lower EC and pH than those of the mixtures with the three composts, which were characterized by EC and pH values increasing with increasing the C rate in the mixture. Both parameters decreased in the order: GC/P> MC/P >GCC/P.

#### *3.2. Shawnee switchgrass*

##### *3.2.1. Germination*

The effects of the HAs at three concentrations and of distilled water only (control) on the germination of Shawnee switchgrass seeds after 8-day are shown in Fig. 1. The numerical data of germination are shown in Table 3 (absolute germination percentage) and Table 4 (absolute length, in cm, of the primary root and shoot of germinated seeds) and Figs. 2 and 3 (same parameters expressed as percentages of those of the control assumed 100%).

After 2 days, no seed germination was observed. After 5 days, with respect to the control, a highly significant increase (0.01 P) of germination % was measured only for the treatment MC-HA at 200 mg L<sup>-1</sup> (Table 3 and Fig. 2). After 8 days, with respect to the control, a significant increase (0.05 P) of germination % was measured for the treatments MC-HA at 10 mg L<sup>-1</sup> and GCC-HA at 200 mg L<sup>-1</sup>, and a highly significant increase was measured for the treatments MC-HA at 50 mg L<sup>-1</sup> (0.01 P) and 200 mg L<sup>-1</sup> (0.001 P) (Table 3 and Fig. 2).

Numerical data in Table 4 and Fig. 3 indicate, with respect to the control, a significant positive effect in promoting primary root growth for GC-HA at 10 mg L<sup>-1</sup> (0.01 P), MC-HA at 50 mg L<sup>-1</sup> (0.05 P) and GCC-HA at 50 and 200 mg L<sup>-1</sup> (0.05 P). Data also indicate, with respect to the control, a significant positive effect in promoting primary shoot growth exerted by GC-HA at 10 mg L<sup>-1</sup> (0.05 P) (Table 4 and Fig. 3).

In the experiments with the diluted Nitsch nutrient solution used as the germination medium, the germination percentage of Shawnee switchgrass after 5 days, differently from the response of slickspot peppergrass to the salt content of the germination medium (see Report n.2), was reduced of 46.7% with respect to the control. However, after 8 days no inhibitory effect on germination was observed and no significant differences of length of primary root and shoot of Shawnee switchgrass were measured between the control and the nutrient solution treatment.

### *3.2.2. Early-growth*

The effects of the different substrates on the early growth of Shawnee switchgrass after 33 days are shown in Figure 4. The corresponding numerical data of the length of roots, shoots and primary leaf, and of the plant fresh weight are shown in Table 5 (absolute length, in cm, of roots and shoots) and Table 6 (absolute length, in cm, of primary leaf, and absolute plant fresh weight, in mg) and Figs. 5, 6, and 7 (same parameters expressed as percentages of those of the control assumed 100%).

Numerical data in Table 5 and Fig. 5 indicate, with respect to the peat (P) control, a general highly significant positive effect on the roots and shoots growth exerted by all the mixtures used at any %, with the only exception of GCC/P 5% on shoos growth.

Numerical data in Table 6 and Figs. 6 and 7 indicate, with respect to the control, a general significant or highly significant positive effect exerted by all the mixtures used at any % also on the length of primary leaf, and a significant positive effect on plant fresh weight exerted by GC/P 5% (0.05 P), MC/P 5% and 10% (0.001 P and 0.01 P, respectively), and GCC/P 10% and 20% (0.01 P and 0.001 P, respectively).

In conclusion, when the effects of the different substrates are evaluated comparatively, GC/P and MC/P appear to exert the highest stimulating effects at the lower dose of compost (5%) in the mixtures used as substrates, whereas GCC/P shows the best results at the higher dose of compost (20%).

## 3.3. Alamo switchgrass

### *3.3.1. Germination*

The effects of the HAs at three concentrations and of distilled water only (control) on the germination of Alamo switchgrass seeds after 8-day are shown in Fig. 8, whereas the numerical data of early growth are shown in Table 7 (absolute germination

percentage) and Table 8 (absolute length, in cm, of primary root and shoot of germinated seeds) and Figs. 9 and 10 (same parameters expressed as percentages of those of the control assumed 100%).

After 2 days, with respect to the control, a significant increase (0.05 P) of the germination % was measured for the treatments GC-HA at  $10 \text{ mg L}^{-1}$ , MC-HA at  $50 \text{ mg L}^{-1}$ , and GCC-HA at all concentrations (Table 7 and Fig. 9). After 5 days, with respect to the control, a significant increase of the germination percentage (0.05 P) was measured only for the treatment GC-HA at  $50 \text{ mg L}^{-1}$ , whereas a significant reduction (0.05 P) was measured for the treatments GC-HA at  $200 \text{ mg L}^{-1}$  and MC-HA at  $10 \text{ mg L}^{-1}$  (Table 7 and Fig. 9). After 8 days, with respect to the control, a significant increase of the germination % (0.05 P) was measured only for the treatment GC-HA at  $50 \text{ mg L}^{-1}$  (Table 7 and Fig. 9).

Numerical data in Table 8 and Fig. 10 indicate, with respect to the control, a significant positive effect in promoting primary root growth for GC-HA and GCC-HA at  $50 \text{ mg L}^{-1}$  (0.05 P), and a significant or highly significant positive effect in promoting primary shoot growth exerted by all the HAs used, with the only exception of GC-HA at  $200 \text{ mg L}^{-1}$ .

In the experiments with diluted Nitsch nutrient solution used as the germination medium, no significant differences of both the germination percentage and the length of primary root and shoot of Alamo switchgrass were measured with respect to the control up to 8 days of germination.

### 2.3.2. Early-growth

The effects of the different substrates on the early growth of Alamo switchgrass after 33 days are shown in Figure 11, whereas the corresponding numerical data of the length of roots, shoots and primary leaf, and of the plant fresh weight are shown in Table 9 (absolute length, in cm, of roots and shoots) and Table 10 (absolute length, in cm, of primary leaf, and absolute plant fresh weight, in mg) and Figs. 12, 13, and 14 (same parameters expressed as percentages of those of the control assumed 100%).

Numerical data in Table 9 and Fig. 12 indicate, with respect to the peat (P) control, a significant or highly significant positive effect on the roots growth exerted by all the three C/P substrates at 10% (0.01 P), and by the GCC/P substrates at 5 and 20% (0.05 P). A significant or highly significant positive effect was measured also on the shoots

growth in the presence of GC/P substrates at 10 and 20% (0.05 P), MC/P substrates at 5 and 10% (0.05 P), and GCC/P substrates at 10 and 20% (0.01 P).

Numerical data in Table 10 and Figs. 13 and 14 indicate, with respect to the control, a general significant or highly significant positive effect exerted by all the mixtures used at any % also on the length of primary leaf, with the only exception of GCC/P at 5%, and a significant or highly significant positive effect on plant fresh weight exerted by all the substrates at 10 and 20%, and by GC/P 5%.

In conclusion, when the effects of the different substrates are evaluated comparatively, all the three mixtures appear to exert the highest stimulating effects at the intermediate dose of compost (10%) in the mixtures used as substrates.

## (2) RESEARCH PLANS FOR REMAINDER OF THE CONTRACT PERIOD

In the 4<sup>th</sup> year (the last) of the contract period, research plans are the following:

- (a) Experiments on the germination and early growth of two additional different species of switchgrass in the presence of, respectively, humic acids isolated from each compost and mixtures of peat and each compost at three different percentages.
- (b) Correlation of the experimental germination and seedling growth data with chemical and physico-chemical parameters of the humic acids isolated from the three composts, in order to find out the parameters that influence germination and early growth of the four switchgrass species examined.
- (c) Possible extension of experiments to different species of switchgrass in the presence of the dissolved organic matter isolated from each compost and mixtures of peat and each compost at three different percentages.

## (3) SIGNIFICANT ADMINISTRATIVE ACTIONS DURING THE PERIOD REPORTED: NONE.

## (4) ANY OTHER INFORMATION : NONE.

## (5) ANNEX

- (A) AMOUNT OF UNUSED FUNDS REMAINING ON THE CONTRACT AT THE END OF THE PERIOD COVERED BY THE REPORT: NONE
- (B) IMPORTANT PROPERTIES ACQUIRED WITH CONTRACT DURING THIS PERIOD: NONE.
- (C) METHOD OF REPRODUCTION: E-MAIL ATTACHMENTS, PHOTOCOPYING.

**TABLE 1.** Main properties of the three composts and corresponding HAs examined.

Original Substrates	pH	EC (dS/m)	Moisture (g kg <sup>-1</sup> )	Ash (g kg <sup>-1</sup> )	TOC (g kg <sup>-1</sup> )	Total N (g kg <sup>-1</sup> )	C/N ratio
GC	8.4	3.73	163	651	184	15.6	11.7
MC	8.5	3.64	120	628	196	17.2	11.4
GCC	9.1	3.30	147	150	424	25.7	16.5
HAs	As h	COOH (meq g <sup>-1</sup> )	Phenolic OH (meq g <sup>-1</sup> )	Total acidity	E <sub>4</sub> /E <sub>6</sub> ratio		
GC-HA	3.4	3.34	1.80	5.14	8.24		
MC-HA	3.2	3.38	2.94	6.32	8.08		
GCC-HA	4.9 <sub>6</sub>	3.08	2.55	5.63	8.54		

**TABLE 2.** Electrical conductivity and pH values of the suspensions of the growth substrates used in distilled water (1:15, w/v).

<b>Growth substrates</b>	<b>EC (<math>\mu\text{S cm}^{-1}</math>)</b>	<b>pH</b>
P	268	4.35
GC/P 5%	819	6.22
GC/P 10%	1130	6.42
GC/P 20%	1182	7.05
MC/P 5%	595	6.10
MC/P 10%	794	6.56
MC/P 20%	1113	7.12
GCC/P 5%	658	5.59
GCC/P 10%	689	5.68
GCC/P 20%	834	6.14

**TABLE 3.** Effect of compost HAs at three different concentrations on seed germination (percentage of germinated seeds  $\pm$  standard error for three replicates) of Shawnee switchgrass measured after three subsequent time periods.

<b>Treatment</b>	Concentration (mg L <sup>-1</sup> )	Germination (%)	
		after 5 days	after 8 days
Control		50.0 $\pm$ 2.36	53.3 $\pm$ 2.72
GC-HA	10	40.0 $\pm$ 4.08	48.3 $\pm$ 5.93
	50	45.0 $\pm$ 2.36	55.0 $\pm$ 2.36
	200	40.0 $\pm$ 4.08	46.7 $\pm$ 5.93
MC-HA	10	51.7 $\pm$ 2.72	61.7 $\pm$ 1.36 *
	50	48.3 $\pm$ 2.72	66.7 $\pm$ 1.36 **
	200	71.7 $\pm$ 3.60 **	75.0 $\pm$ 2.36 ***
GCC-HA	10	50.0 $\pm$ 2.36	58.3 $\pm$ 2.72
	50	50.0 $\pm$ 6.24	61.7 $\pm$ 1.36
	200	55.0 $\pm$ 0.00	63.3 $\pm$ 1.36 *

\*\*\* P  $\leq$  0.001; \*\* P  $\leq$  0.01; \* P  $\leq$  0.05, according to the LSD test. Standard errors (n = 3) are also indicated.

**TABLE 4.** Effect of compost HAs at three different concentrations on the lengths (cm  $\pm$  standard error for three replicates) of primary root and primary shoot of Shawnee switchgrass after 8-day growth.

Treatment	Concentration (mg L <sup>-1</sup> )	Root length	Shoot length
Control		0.3 $\pm$ 0.00	0.5 $\pm$ 0.05
GC-HA	10	0.7 $\pm$ 0.07 **	0.8 $\pm$ 0.06 *
	50	0.3 $\pm$ 0.02	0.5 $\pm$ 0.01
	200	0.4 $\pm$ 0.06	0.6 $\pm$ 0.08
MC-HA	10	0.4 $\pm$ 0.04	0.6 $\pm$ 0.05
	50	0.5 $\pm$ 0.01 *	0.6 $\pm$ 0.04
	200	0.4 $\pm$ 0.04	0.7 $\pm$ 0.08
GCC-HA	10	0.4 $\pm$ 0.03	0.6 $\pm$ 0.06
	50	0.5 $\pm$ 0.03 *	0.7 $\pm$ 0.06
	200	0.5 $\pm$ 0.03 *	0.5 $\pm$ 0.05

\*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test. Standard errors (  $n = 3$  ) are also indicated.

**TABLE 5.** Effect of peat and mixtures of each compost and peat on the lengths (cm  $\pm$  standard error for three replicates) of roots and shoots of Shawnee switchgrass after 33-day growth.

Treatment	% (v/v)	Roots length	Shoots length
Peat		0.9 $\pm$ 0.07	1.3 $\pm$ 0.05
GC/P	5	2.2 $\pm$ 0.12 ***	2.1 $\pm$ 0.02 **
	10	1.6 $\pm$ 0.07 **	1.8 $\pm$ 0.04 *
	20	1.7 $\pm$ 0.14 **	1.9 $\pm$ 0.19 **
MC/P	5	2.6 $\pm$ 0.16 ***	2.3 $\pm$ 0.05 ***
	10	2.2 $\pm$ 0.18 ***	2.3 $\pm$ 0.16 ***
	20	1.7 $\pm$ 0.05 **	2.1 $\pm$ 0.11 **
GCC/P	5	1.5 $\pm$ 0.15 *	1.7 $\pm$ 0.08
	10	2.4 $\pm$ 0.14 ***	2.6 $\pm$ 0.20 ***
	20	2.4 $\pm$ 0.08 ***	2.3 $\pm$ 0.02 ***

\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test. Standard errors (  $n = 3$  ) are also indicated.

**TABLE 6.** Effect of peat and mixtures of each compost and peat on the lengths (cm  $\pm$  standard error for three replicates) of primary leaf and plant fresh weight (mg  $\pm$  standard error for three replicates) of Shawnee switchgrass after 33-day growth.

Treatment	% (v/v)	Primary leaf	Plant fresh weight
Peat		1.7 $\pm$ 0.06	7.4 $\pm$ 0.29
GC/P	5	5.4 $\pm$ 0.50 ***	11.6 $\pm$ 1.04 *
	10	4.8 $\pm$ 0.22 **	11.0 $\pm$ 0.86
	20	3.4 $\pm$ 0.46 *	11.2 $\pm$ 1.41
MC/P	5	8.0 $\pm$ 0.40 ***	17.5 $\pm$ 1.07 ***
	10	5.4 $\pm$ 0.66 ***	16.0 $\pm$ 1.43 **
	20	4.0 $\pm$ 0.32 *	10.8 $\pm$ 0.86
GCC/P	5	4.3 $\pm$ 0.86 *	9.6 $\pm$ 1.08
	10	6.7 $\pm$ 0.05 ***	12.9 $\pm$ 1.0 **
	20	7.2 $\pm$ 0.18 ***	16.2 $\pm$ 0.83 ***

\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test. Standard errors (  $n = 3$  ) are also indicated.

**TABLE 7.** Effect of compost HAs at three different concentrations on seed germination (percentage of germinated seeds  $\pm$  standard error for three replicates) of Alamo switchgrass measured after three subsequent time periods.

Treatment	Concentration (mg L <sup>-1</sup> )	Germination after 2 days (%)	Germination after 5 days (%)	Germination after 8 days (%)
Control		10.0 $\pm$ 2.36	46.7 $\pm$ 3.60	46.7 $\pm$ 3.60
GC-HA	10	18.3 $\pm$ 1.36 *	45.0 $\pm$ 2.36	55.0 $\pm$ 2.36
	50	15.0 $\pm$ 2.36	60.0 $\pm$ 2.36 *	60.0 $\pm$ 2.36 *
	200	6.7 $\pm$ 1.36	36.7 $\pm$ 1.36 *	48.3 $\pm$ 3.60
MC-HA	10	11.7 $\pm$ 1.36	33.3 $\pm$ 1.36 *	38.3 $\pm$ 3.60
	50	18.3 $\pm$ 1.36 *	43.3 $\pm$ 2.72	46.7 $\pm$ 4.91
	200	15.0 $\pm$ 0.0	41.7 $\pm$ 1.36	46.7 $\pm$ 3.60
GCC-HA	10	20.0 $\pm$ 0.0 *	43.3 $\pm$ 2.72	50.0 $\pm$ 4.08
	50	20.0 $\pm$ 2.36 *	50.0 $\pm$ 4.08	53.3 $\pm$ 3.60
	200	18.3 $\pm$ 1.36 *	40.0 $\pm$ 2.36	51.7 $\pm$ 1.36

\*  $P \leq 0.05$ , according to the LSD test. Standard errors (n = 3) are also indicated.

**TABLE 8.** Effect of compost HAs at three different concentrations on the lengths (cm  $\pm$  standard error for three replicates) of primary root and primary shoot of Alamo switchgrass after 8-day growth.

Treatment	Concentration (mg L <sup>-1</sup> )	Root length	Shoot length
Control		0.6 $\pm$ 0.06	0.8 $\pm$ 0.02
GC-HA	10	0.7 $\pm$ 0.03	1.1 $\pm$ 0.09 *
	50	0.9 $\pm$ 0.10 *	1.0 $\pm$ 0.03 *
	200	0.5 $\pm$ 0.03	0.9 $\pm$ 0.06
MC-HA	10	0.6 $\pm$ 0.08	1.0 $\pm$ 0.03 *
	50	0.7 $\pm$ 0.04	1.1 $\pm$ 0.05 **
	200	0.7 $\pm$ 0.04	1.2 $\pm$ 0.05 ***
GCC-HA	10	0.7 $\pm$ 0.05	1.0 $\pm$ 0.03 *
	50	0.8 $\pm$ 0.06 *	1.3 $\pm$ 0.07 ***
	200	0.6 $\pm$ 0.02	1.1 $\pm$ 0.03 **

\*\*\* P  $\leq$  0.001; \*\* P  $\leq$  0.01; \* P  $\leq$  0.05, according to the LSD test. Standard errors ( n = 3) are also indicated.

**TABLE 9.** Effect of peat and mixtures of each compost and peat on the lengths (cm  $\pm$  standard error for three replicates) of roots and shoots of Alamo switchgrass after 33-day growth.

Treatment	% (v/v)	Roots length	Shoots length
Peat		1.4 $\pm$ 0.12	1.2 $\pm$ 0.09
GC/P	5	1.7 $\pm$ 0.08	1.5 $\pm$ 0.13
	10	2.1 $\pm$ 0.08 **	1.7 $\pm$ 0.08 *
	20	1.4 $\pm$ 0.08	1.7 $\pm$ 0.05 *
MC/P	5	1.8 $\pm$ 0.12	1.7 $\pm$ 0.12 *
	10	2.4 $\pm$ 0.22 **	1.8 $\pm$ 0.13 *
	20	1.5 $\pm$ 0.11	1.6 $\pm$ 0.11
GCC/P	5	1.9 $\pm$ 0.05 *	1.5 $\pm$ 0.12
	10	2.1 $\pm$ 0.06 **	2.1 $\pm$ 0.16 **
	20	2.0 $\pm$ 0.15 *	2.1 $\pm$ 0.08 **

\*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test. Standard errors (n = 3) are also indicated.

**TABLE 10.** Effect of peat and mixtures of each compost and peat on the lengths (cm  $\pm$  standard error for three replicates) of primary leaf and plant fresh weight (mg  $\pm$  standard error for three replicates) of Alamo switchgrass after 33-day growth.

Treatment	% (v/v)	Primary leaf	Plant fresh weight
Peat		2.1 $\pm$ 0.12	7.1 $\pm$ 0.31
GC/P	5	4.2 $\pm$ 0.60 **	10.0 $\pm$ 0.90 *
	10	3.9 $\pm$ 0.11 *	10.9 $\pm$ 0.35 **
	20	3.4 $\pm$ 0.18 *	10.0 $\pm$ 0.73 *
MC/P	5	4.0 $\pm$ 0.58 *	9.6 $\pm$ 0.20
	10	4.5 $\pm$ 0.48 **	11.6 $\pm$ 1.34 ***
	20	3.9 $\pm$ 0.09 *	10.6 $\pm$ 0.35 *
GCC/P	5	2.8 $\pm$ 0.16	7.3 $\pm$ 1.19
	10	4.9 $\pm$ 0.32 ***	11.7 $\pm$ 0.85 ***
	20	5.0 $\pm$ 0.25 ***	12.3 $\pm$ 0.22 ***

\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test. Standard errors ( $n = 3$ ) are also indicated.

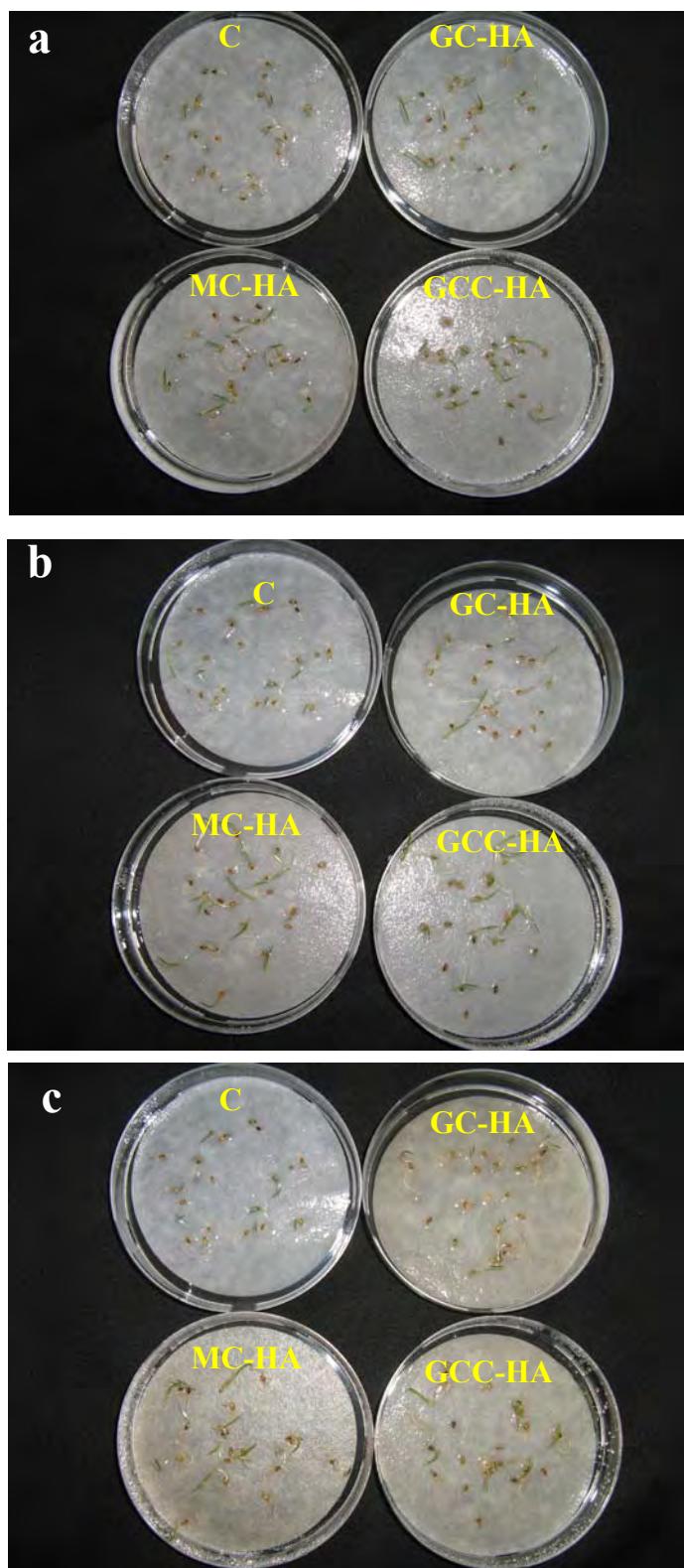
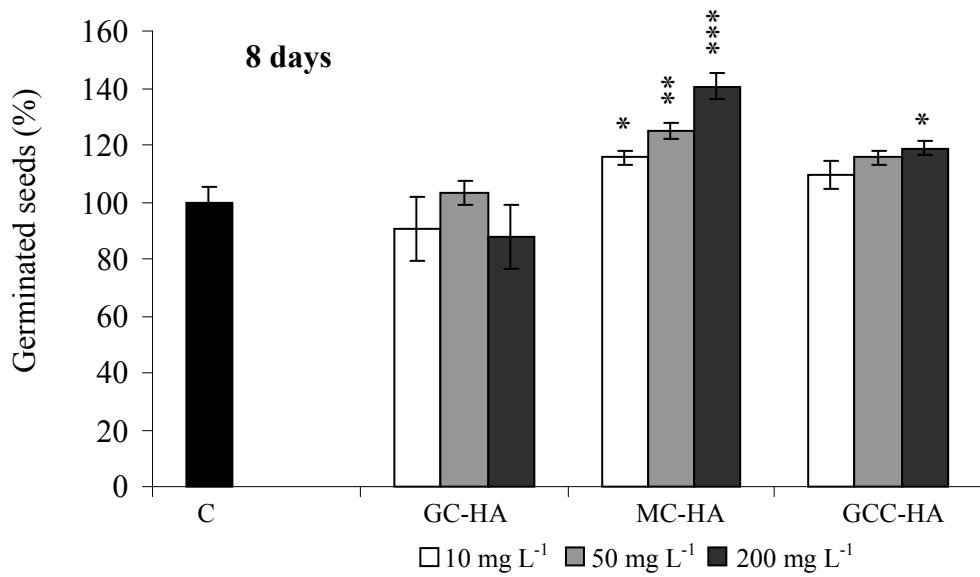
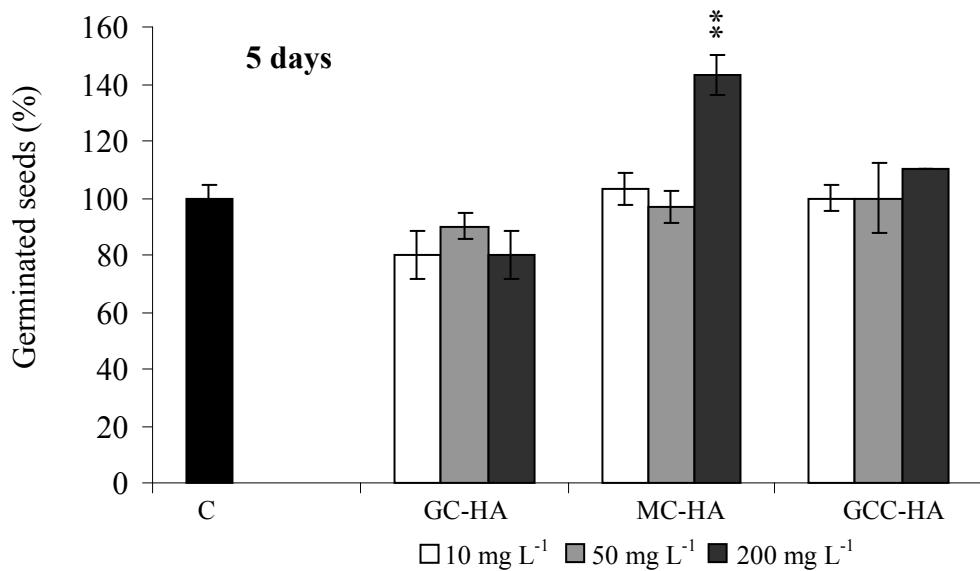
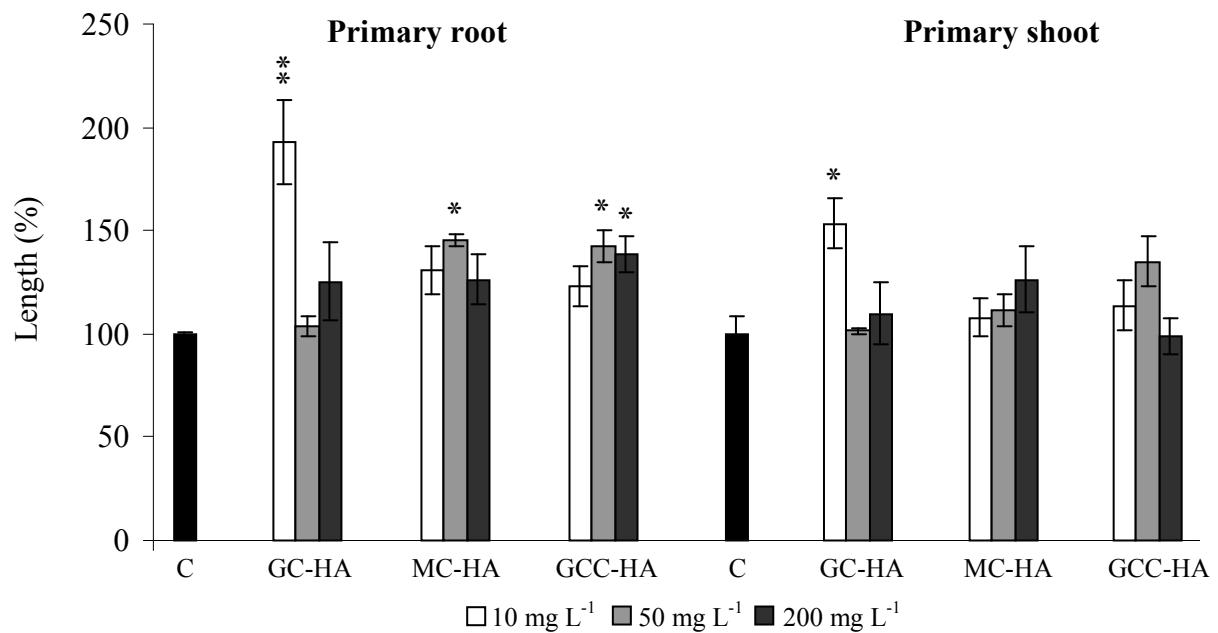


Figure 1. Effect of compost HAs at  $10 \text{ mg L}^{-1}$  (a),  $50 \text{ mg L}^{-1}$  (b), and  $200 \text{ mg L}^{-1}$  (c) on the germination of Shawnee switchgrass seeds after 8 days.



\*\*\* P ≤ 0.001; \*\* P ≤ 0.01; \* P ≤ 0.05, according to the LSD test.

Figure 2. Effect of compost HAs at different concentrations on the number of germinated seeds of Shawnee switchgrass expressed as percentages of control (C, 100 %) after two germination periods. The vertical line on each bar indicates the standard error for 3 replicates.



\*\* P ≤ 0.01; \* P ≤ 0.05, according to the LSD test.

Figure 3. Effect of compost HAs at different concentrations on the length of primary root and shoot of Shawnee switchgrass expressed as percentages of control (C, 100 %) measured after 8-day growth. The vertical line on each bar indicates the standard error for three replicates.

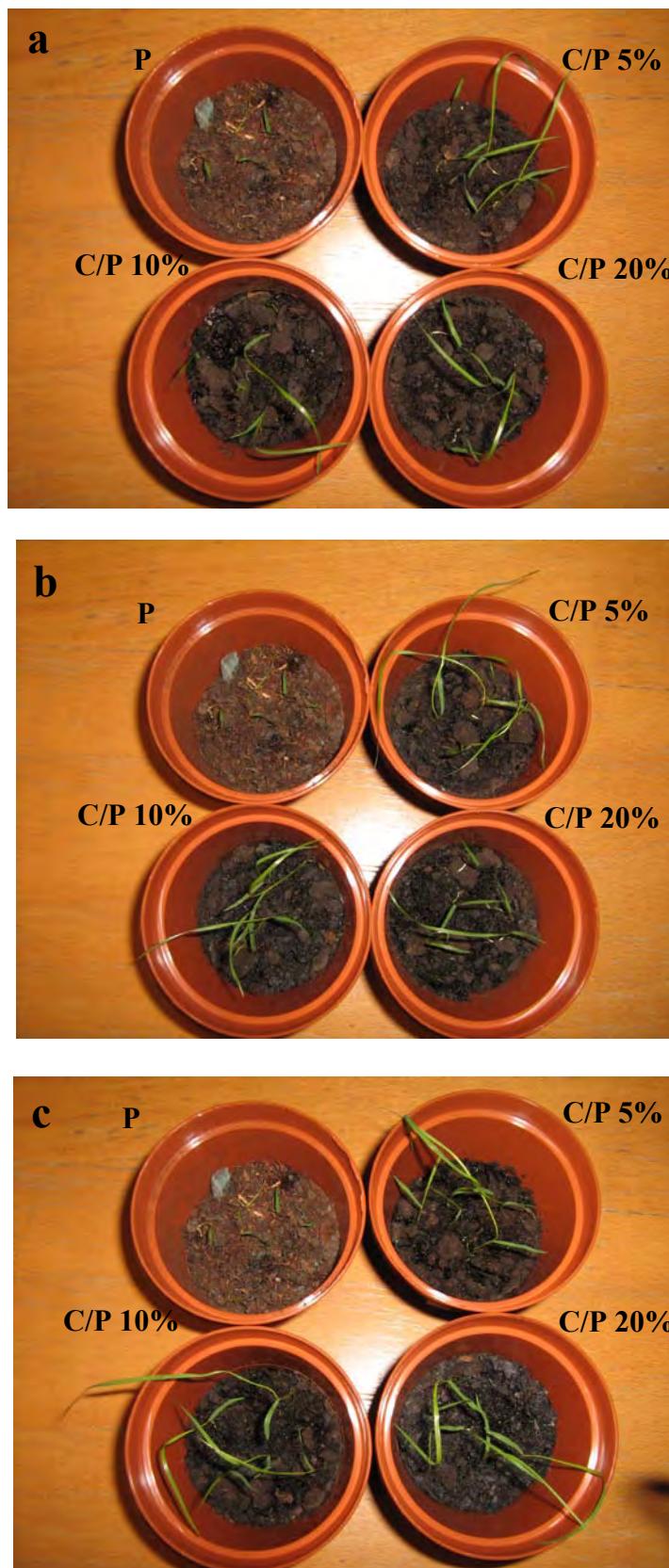
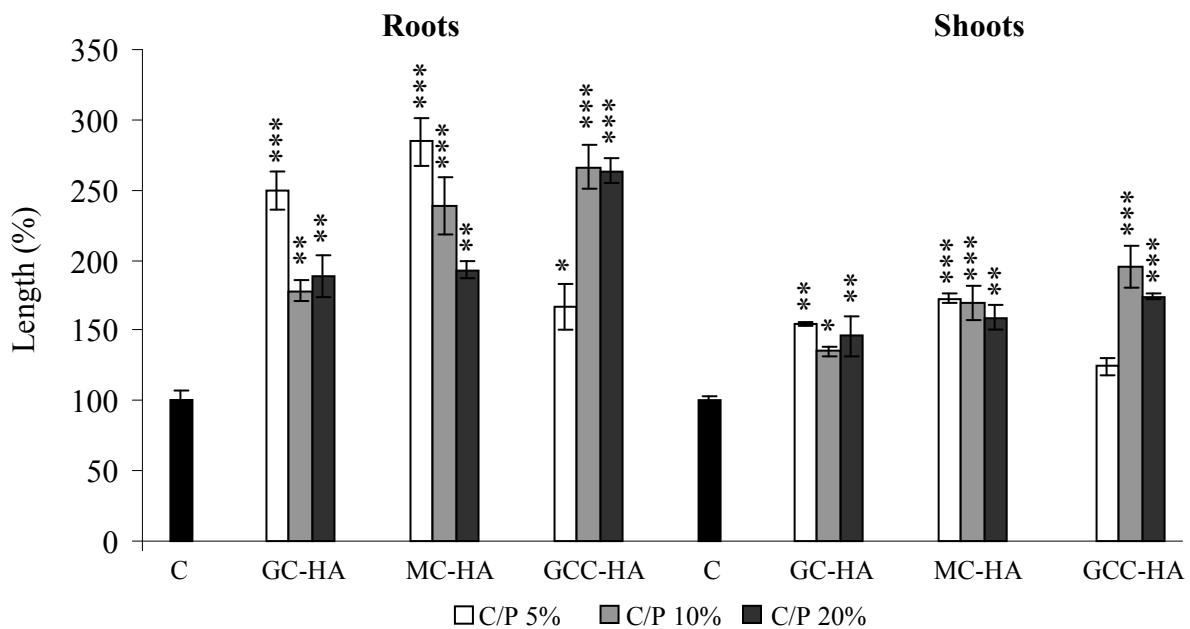
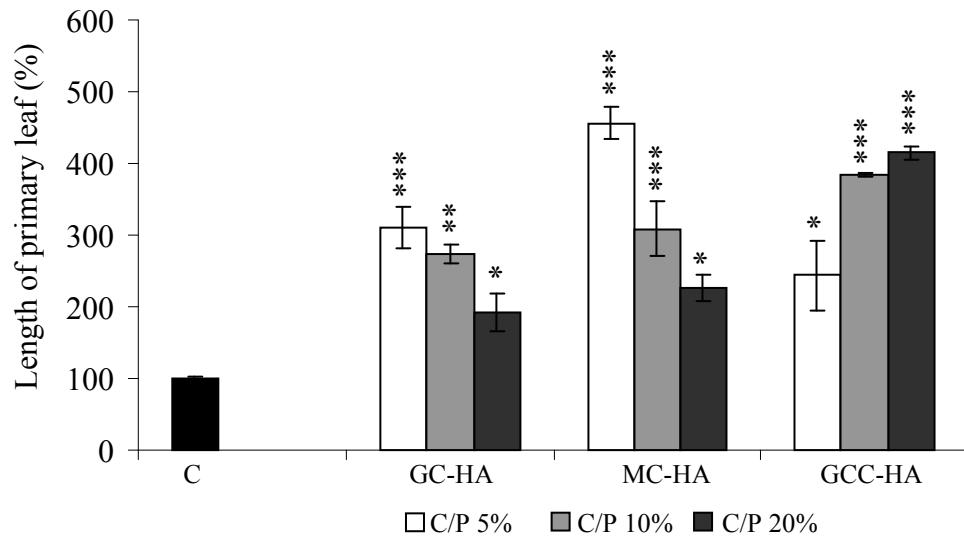


Figure 4. Effects of the mixtures GC/P (a), MC/P (b), and GCC/P (c) at different percentages of compost (v/v) on the growth of Shawnee switchgrass after 33 days.



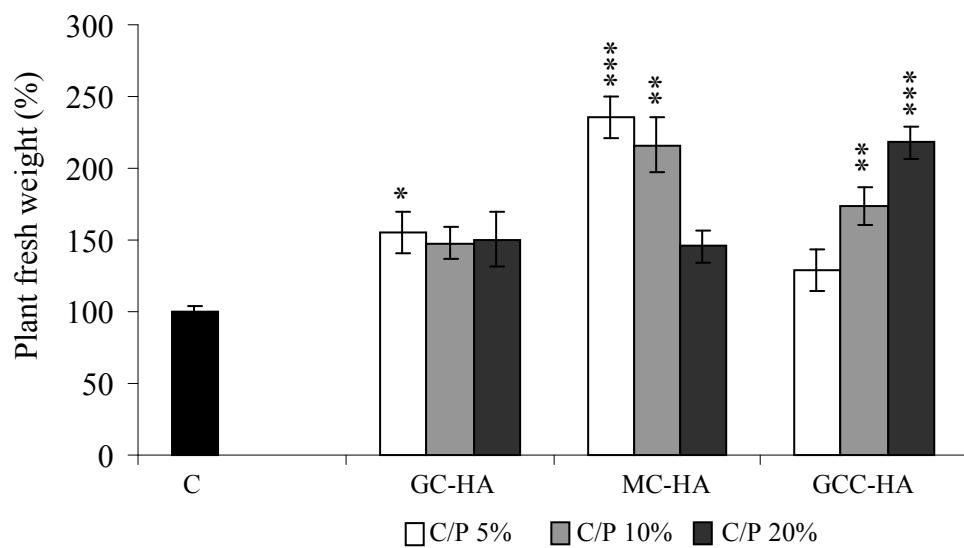
\*\*\* P ≤ 0.001; \*\* P ≤ 0.01; \* P ≤ 0.05, according to the LSD test.

Figure 5. Effect of peat (C, control) and mixtures of each compost and peat on the lengths of roots and shoots of Shawnee switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.



\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test.

Figure 6. Effect of peat (C, control) and mixtures of each compost and peat on the length of primary leaf of Shawnee switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.



\*\*\* P ≤ 0.001; \*\* P ≤ 0.01; \* P ≤ 0.05, according to the LSD test.

Figure 7. Effect of peat (C, control) and mixtures of each compost and peat on the plant fresh weight of Shawnee switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.

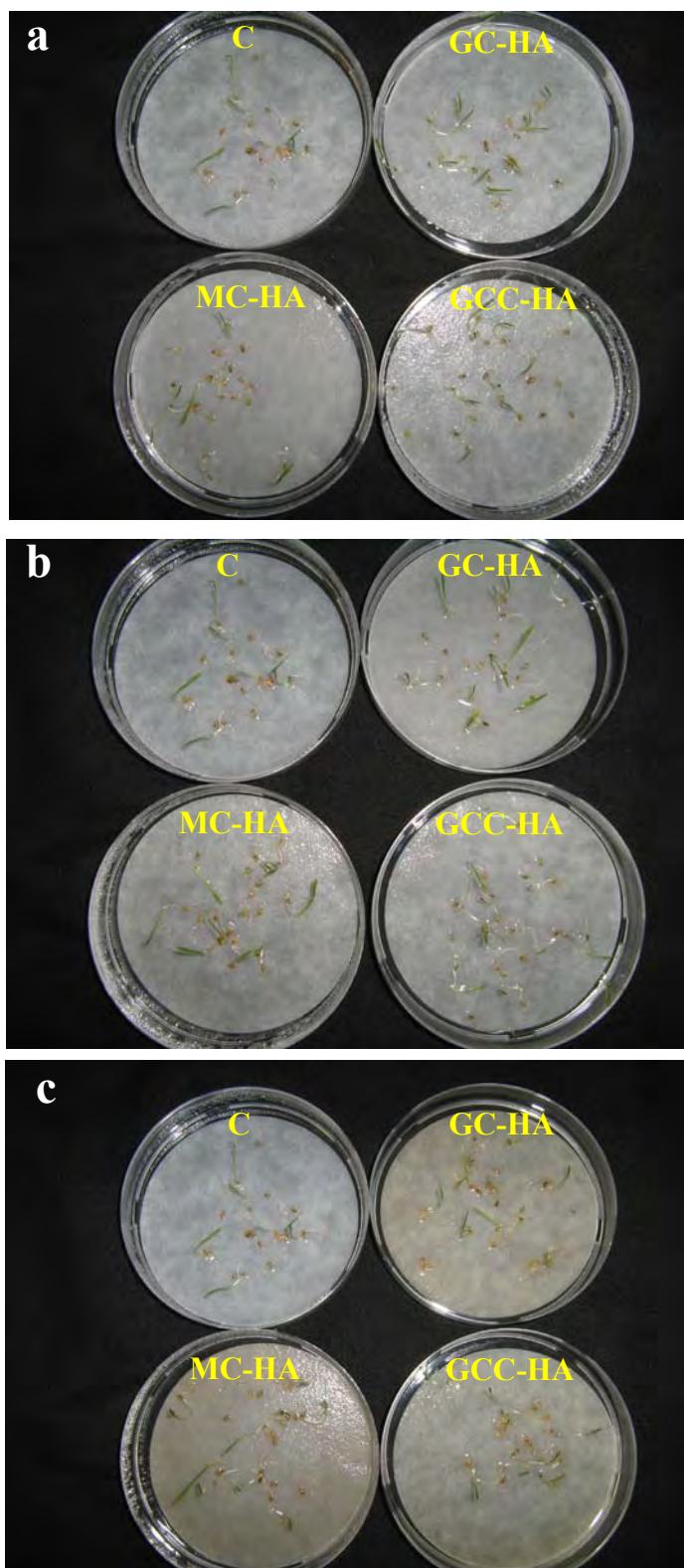
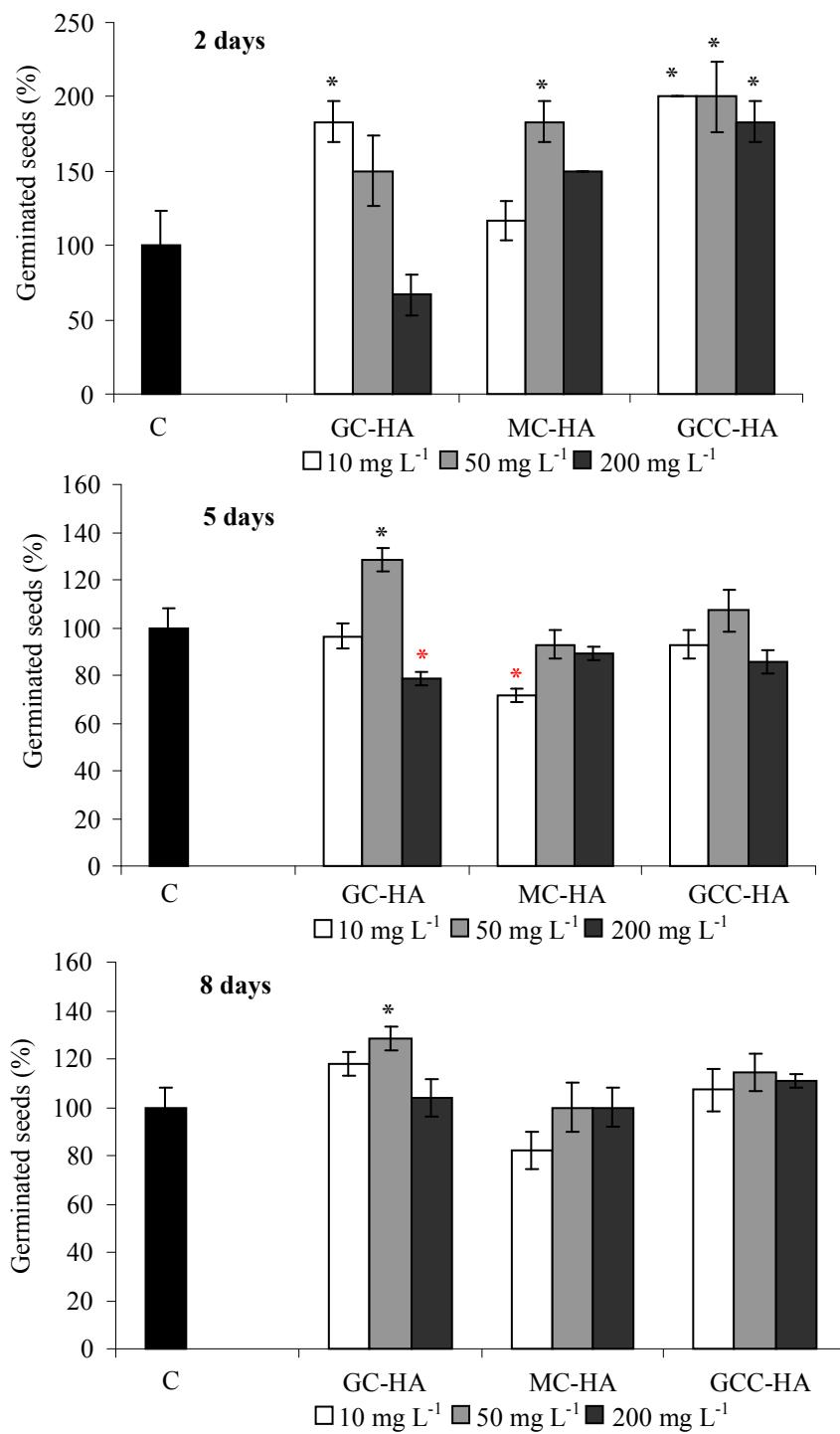
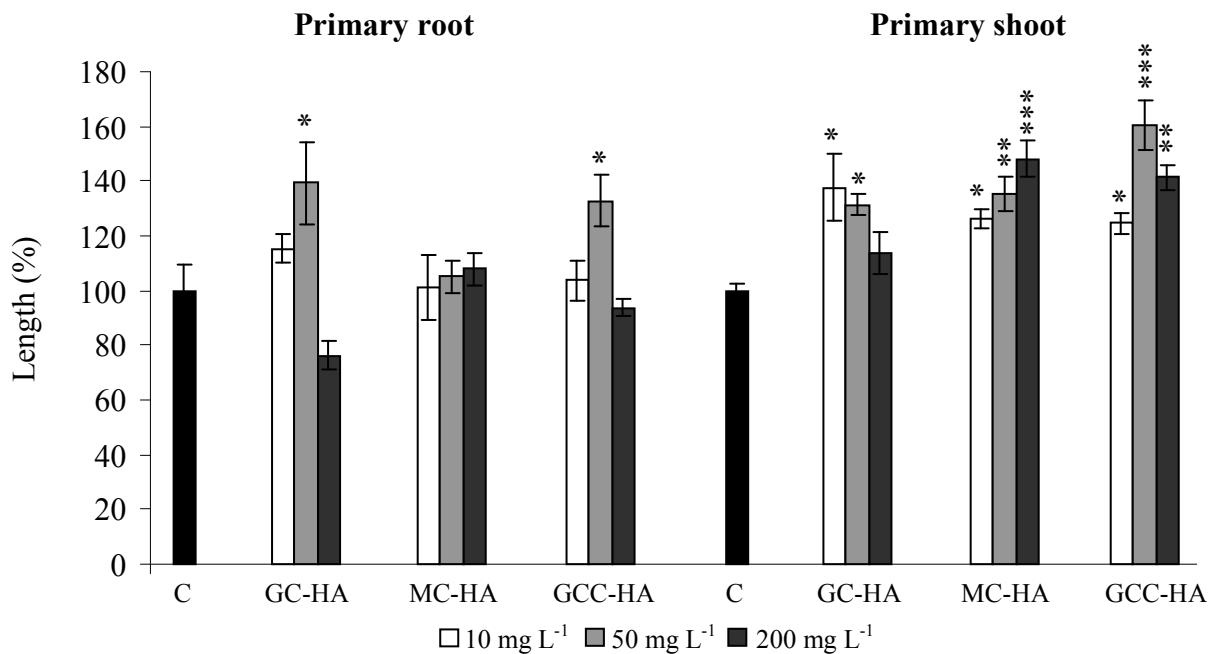


Figure 8. Effects of compost HAs at  $10 \text{ mg L}^{-1}$  (a),  $50 \text{ mg L}^{-1}$  (b), and  $200 \text{ mg L}^{-1}$  (c) on the germination of Alamo switchgrass seeds after 8 days.



\* P ≤ 0.05, according to the LSD test.

Figure 9. Effect of compost HAs at different concentrations on the number of germinated seeds of Alamo switchgrass expressed as percentages of control (C, 100 %) after three germination periods. The vertical line on each bar indicates the standard error for 3 replicates.



\*\*\* P ≤ 0.001; \*\* P ≤ 0.01; \* P ≤ 0.05, according to the LSD test.

Figure 10. Effect of compost HAs at different concentrations on the length of primary root and shoot of Alamo switchgrass expressed as percentages of control (C, 100 %) measured after 8-day growth. The vertical line on each bar indicates the standard error for three replicates.

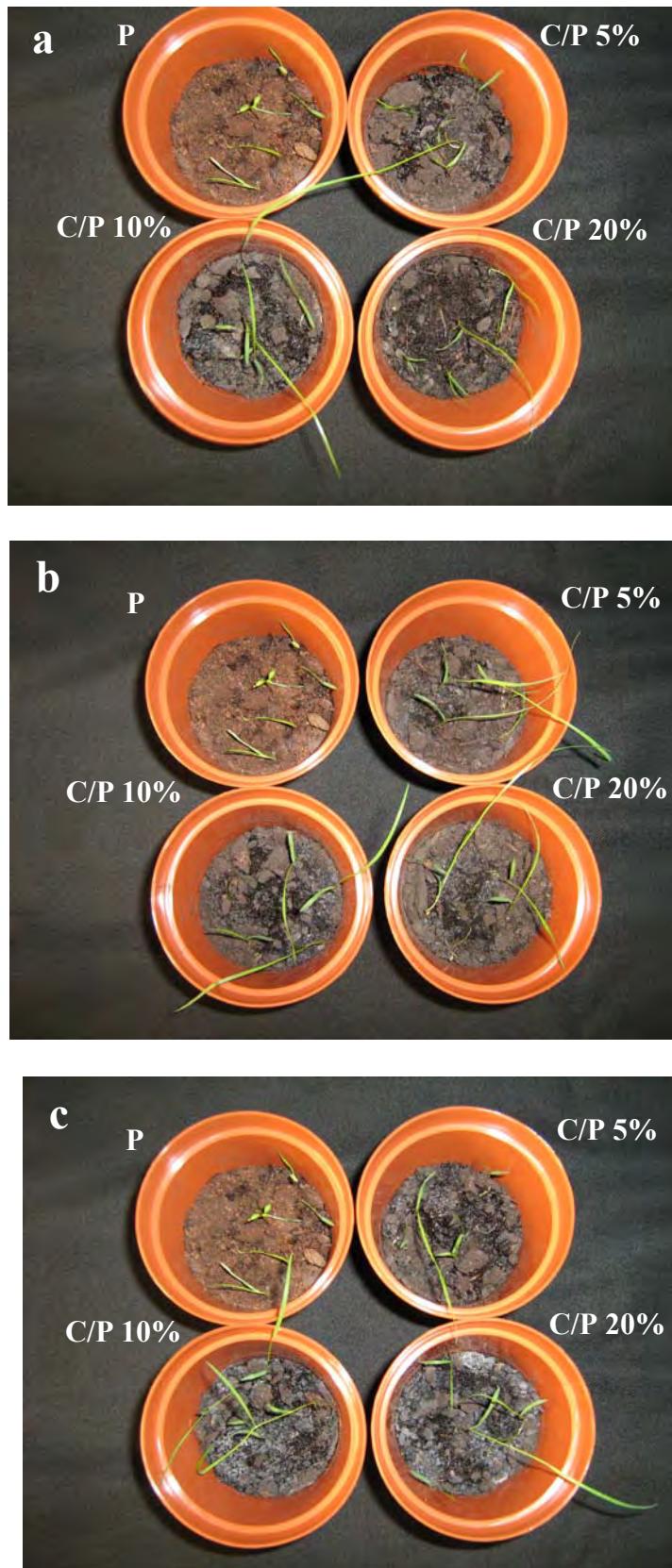
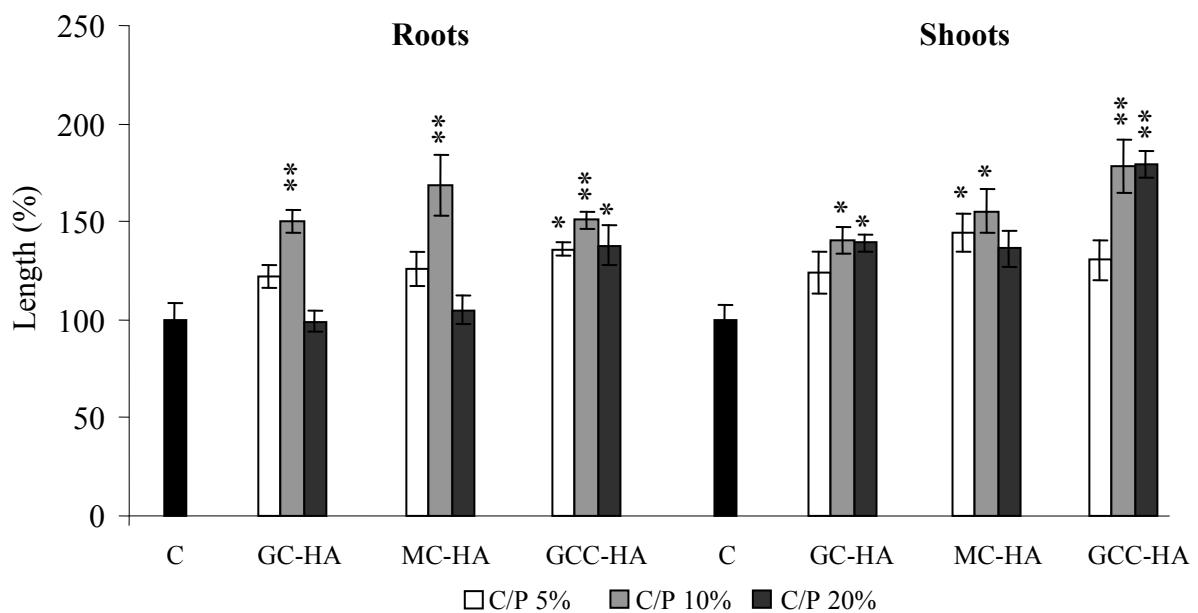
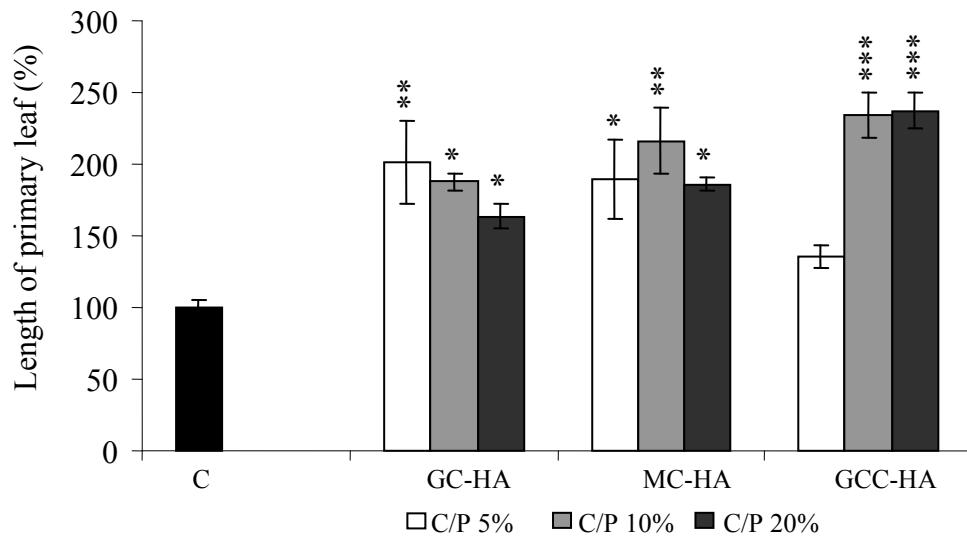


Figure 11. Effects of the mixtures GC/P (a), MC/P (b), and GCC/P (c) at different percentages of compost (v/v) on the growth of Alamo switchgrass after 33 days.



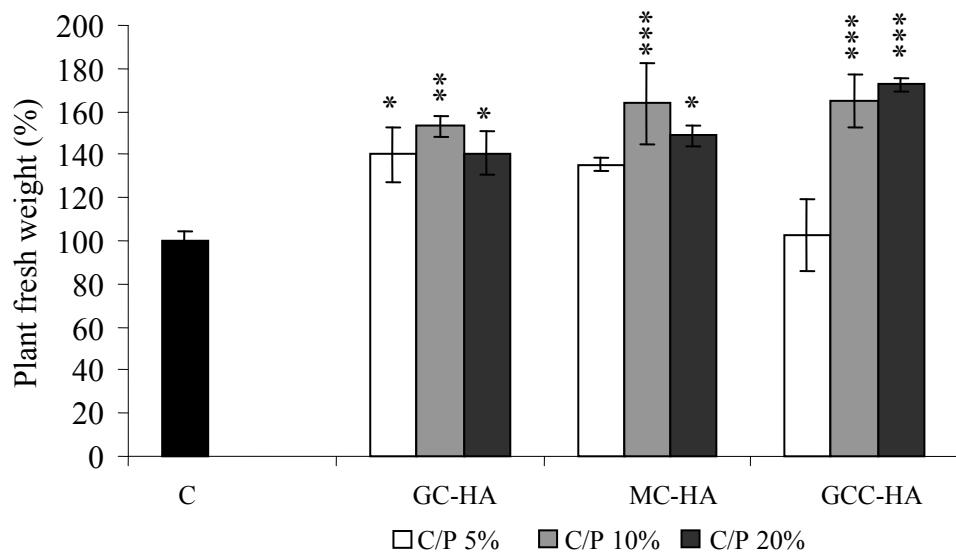
\*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test.

Figure 12. Effect of peat (C, control) and mixtures of each compost and peat on the lengths of roots and shoots of Alamo switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.



\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test.

Figure 13. Effect of peat (C, control) and mixtures of each compost and peat on the length of primary leaf of Alamo switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.



\*\*\*  $P \leq 0.001$ ; \*\*  $P \leq 0.01$ ; \*  $P \leq 0.05$ , according to the LSD test.

Figure 14. Effect of peat (C, control) and mixtures of each compost and peat on the plant fresh weight of Alamo switchgrass expressed as percentages of control (C, 100 %) measured after 33-day growth. The vertical line on each bar indicates the standard error for three replicates.